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# Bonding Lexan and Sapphire to Form High-Pressure, Flame-Resistant Window

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# BONDING LEXAN AND SAPPHIRE TO FORM HIGH-PRESSURE, FLAME-RESISTANT WINDOW

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## SUMMARY

Flammable materials have been studied under laboratory conditions in normal gravity and microgravity for many years. Photography plays a major role in the study of the combustion process as it gives a permanent visual record that can be analyzed. When these studies are extended into manned spacecraft, personnel safety becomes a primary concern. The need for a high-pressure, flame-resistant, shatter-resistant window permitting photographic recording of combustion experiments in manned spacecraft prompted the development of a method for bonding Lexan and sapphire. Materials that resist shattering (e.g., Lexan) are not compatible with combustion experiments as the material loses strength at combustion temperatures. Sapphire is compatible with combustion temperatures in oxygen-enriched atmospheres but is subject to shattering. Combining the two materials results in a shatter-resistant, flame-resistant window. Combustion in microgravity produces a low-visibility flame; however, flame propagation and flame characteristics are readily visible as long as there is no deterioration of the image. Since an air gap between the Lexan and the sapphire would reduce transmission, a method was developed for bonding these unlike materials to minimize light loss.

## TRANSMISSION MEASUREMENTS

The Lexan-sapphire windows were developed for use in recording combustion in microgravity, where the absence of convection results in a barely visible flame. The development of a bonding procedure was necessary because of the large size and irregular shape of the windows. According to measurements made with a Macbeth transmission densitometer in the visible light spectrum (~400 to 700 μm), the window material absorbs some of the light. The outer window surface, a 1/2-inch-thick Lexan block, 2-3/4 inches by 5-1/4 inches, was measured first. The typical result, as shown in table I, was a transmission density (light loss) of 0.06 to 0.09, where 0.30 equals one f-stop. The sapphire material density measured consistently 0.02. When the two materials were sandwiched but not bonded, the expected density of 0.08 to 0.11 actually was 0.13 to 0.16.

In an effort to improve the transmission, we decided to bond the two materials with an ultraviolet-curable optical adhesive and thus eliminate the air space. Norland optical adhesive #61 was tested first as it met MIL-A-3920 and was approved for all government contracts specifying such adhesives. The use of an approved bonding agent would simplify approval for use in crew quarters aboard the space shuttle.

The use of #61 was discontinued after several windows separated during, or within 24 hours of, curing. Several different holding arrangements were tried including clamping the windows with spring clamps, elastics, or wire for the

curing process. In addition, changes in cleaning agents, bonding agents, light sources, and exposure times were tried in an effort to get a good clear bond without any separation. The successful method involved the use of Norland optical adhesive #68. The adhesive also meets MIL-A-3920 and is slightly more flexible than #61.

## PROCEDURE

### Cleaning

The first step in assembling a window was cleaning the surfaces of the two materials. Bonded alcohol and then ammonium hydroxide applied with a cotton pad (Webril Wipes) worked effectively. Several applications of the solutions were necessary, and care had to be taken in scrubbing the Lexan with the cotton pad as the surface could be scratched. The surfaces were then dried with a clean cotton pad and inspected for defects. White cotton gloves were worn during cleaning and assembly.

After cleaning, each window was visually inspected and any imperfections in either the Lexan or the sapphire were documented. An inspection station was made with a black background and illuminated with a strong, directional side light (fig. 1). This inspection station allowed observation of very small defects.

Each surface was then cleaned again with ethyl alcohol (200 proof) and ammonium hydroxide, applied with a cotton pad. The cleaning process was repeated several times until no visible residue remained. Surfaces were then cleaned with ionized air to remove dust and static electric charges.

### Assembly

The flattest side of the Lexan piece was placed face up on a clean, flat surface. Approximately 15 drops of Norland optical adhesive #68 were applied to the surface in a pattern that had been found to spread evenly (fig. 2). Trapped air bubbles were then removed from the cement, and the cement was allowed to stabilize in order to reduce surface depressions that trap air. The sapphire plate was then lowered onto the surface of the cement, pushing trapped air toward the edges ahead of the contact front (fig. 3). The sapphire plate spread the cement, which formed an oval spot between the surfaces (fig. 4).

Small bubbles often remained trapped between the surfaces. Usually they could be forced out by placing a weight between the center of the sample and the air bubble and moving the weight toward the nearest edge to follow the migrating bubble (fig. 5). It generally took about 1/2 hour to get an even spread of cement between the two surfaces and to remove all the air. The weight of the sapphire material forced excess cement from between the two surfaces. When the cement stopped seeping out and the excess had been removed from the edges, the sandwich was placed into the holding fixture. The fixture prevented the sapphire from sliding around on the cement before it became tacky (fig. 6). The sandwiched materials were then exposed to long-wave ultraviolet light for 10 minutes to set the sample. The light source was a Pen-Ray model

SCT-1 placed approximately 2 inches from the sapphire surface. The window was cleaned, inspected, and then exposed to the lamp for 6 hours to cure. During exposure a reflector was placed over the lamp and the window to concentrate the light and to protect personnel (fig. 7).

## Salvaging Sapphire Materials

Early procedures resulted in failures, making it necessary to separate some windows and salvage the sapphire. The first salvaging method used was to soak the window in a solution of bonded alcohol and ammonium hydroxide. The solution dissolved the Lexan material in approximately 24 hours. The sapphire portion of the window was left with a hard residue that required extensive cleaning by hand.

A more successful method of separation was to slowly raise the temperature of the sample in a laboratory oven. The window was placed in a shallow container with the sapphire side up. The container was placed in the cool oven and the temperature was raised to approximately 230 °F over 15 to 20 minutes. The heat released the adhesive and the sapphire could be lifted off. This usually left a layer of adhesive that could be peeled off in sheets. Any remaining residue could be quickly cleaned in solvent.

## TESTING

The completed windows (fig. 8) were installed in a pressure vessel (fig. 9) and hydrostatically tested to 60 psig. The pressure vessel was then pressurized with 2 atmospheres of helium and placed in a vacuum chamber evacuated to $10^{-5}$ torr. A leak check was conducted.

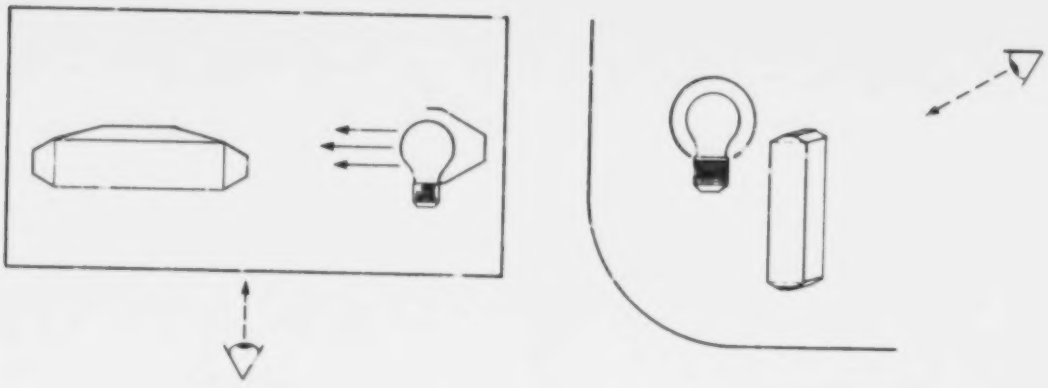
## CONCLUSIONS

Upon completion of the tests the windows showed no sign of separation and remained optically clear. A total of eight windows were fabricated and tested using the procedure outlined. There were no failures. From the results we concluded that this procedure is acceptable for bonding large windows fabricated from unlike materials.

TABLE I. - TRANSMISSION DENSITY OF WINDOW MATERIALS

[Average of eight windows.]

| Material | Transmission density |
|---|---|
| Sapphire | 0.02 |
| Lexan | 0.06 to 0.09 |
| Sapphire-Lexan (unbonded) | 0.13 to 0.16 |
| Sapphire-Lexan (bonded) | 0.08 to 0.11 |



(A) TOP VIEW.

(B) SIDE VIEW.

FIGURE 1. - INSPECTION STATION.

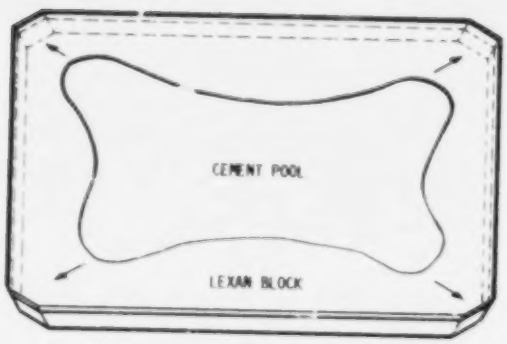
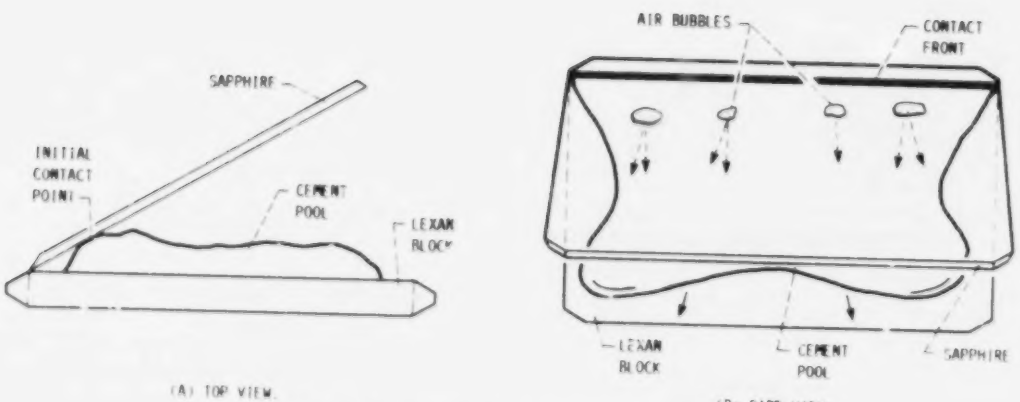



FIGURE 2. - ADHESIVE APPLICATION PATTERN.




(A) TOP VIEW.

(B) SIDE VIEW.

FIGURE 3. - ASSEMBLY OF LEXAN-SAPPHIRE WINDOW.

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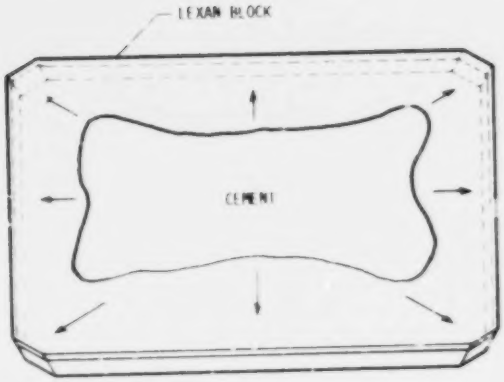


FIGURE 4. - SPREADING OF CEMENT.

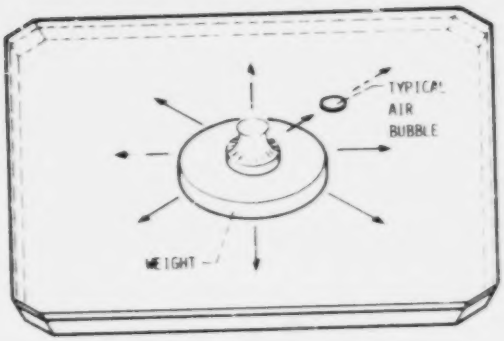


FIGURE 5. - BUBBLE MIGRATION.

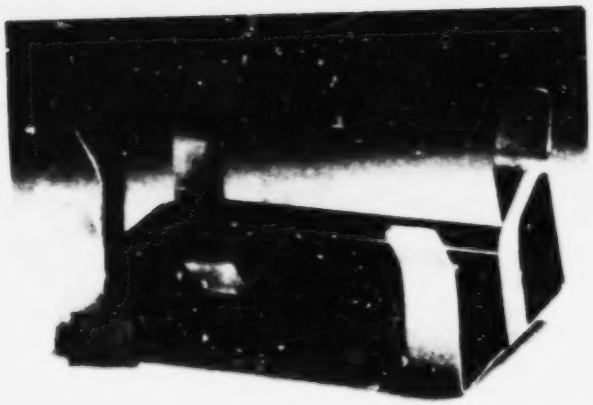

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FIGURE 6. - HOLDING FIXTURE.

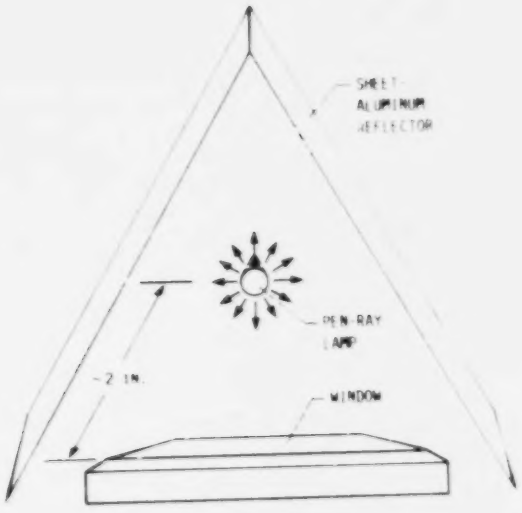


FIGURE 7. - CURING STATION.

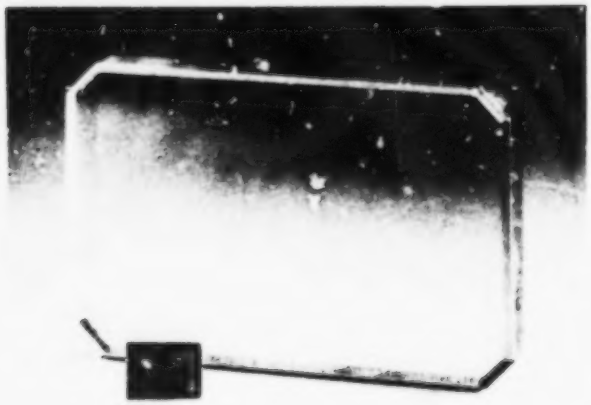

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FIGURE 8. COMPLETED LEXAN SAPPHIRE WINDOW.

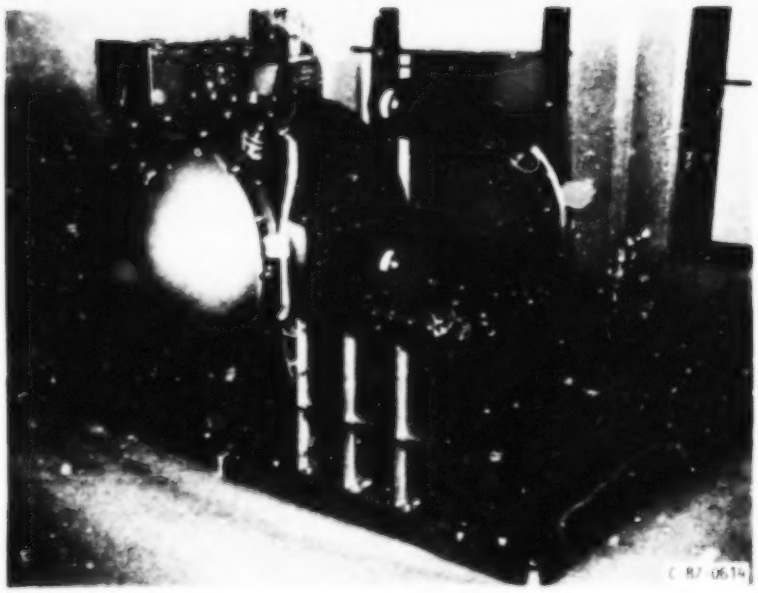

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FIGURE 9. PRESSURE VESSEL.

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